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HUBBLE SPACE TELESCOPE FOURTH SERVICING MISSION (SM4) LEVEL II REQUIREMENTS

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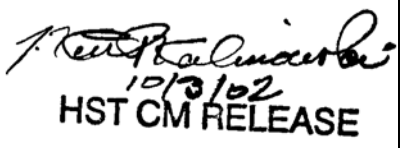
Baseline Issue 8/23/02			CCR 4960 Level 2 CCB Minutes #577 

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TABLES

ACRONYMS

ACS	Advanced Camera for Surveys
ASCS	Aft Shroud Cooling System
CATS	Crew Aids and Tools
CCB	Configuration Control Board
CCC	Charge Current Controller
CCD	Charge Coupled Device
CCS	Control Center System
CEI	Contract End Item
COS	Cosmic Origins Spectrograph
COSTAR	Corrective Optics – Space Telescope Axial Replacement
DMU	Data Management Unit
DMS	Data Management Subsystem
DSC	DMU to SI C&DH Cross-Strap
ECU	Electronics Control Unit
EPS	Electrical Power Subsystem
EVA	Extra Vehicular Activity
FGS	Fine Guidance Sensor
FSS	Flight Support System
FSW	Flight Software
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

ACRONYMS (Continued)

HFMS	High Fidelity Mechanical Simulator
HST	Hubble Space Telescope
ICD	Interface Control Document
IR	Infrared
JSC	Johnson Space Center
KHB	Kennedy Space Center Handbook
KSC	Kennedy Space Center
LOS	Line of Sight
MLI	Multi-Layer Insulation
ME	Mission Engineering
MS	Mission Science
NASA	National Aeronautics and Space Administration
NCS	NICMOS Cooling System
NICMOS	Near-Infrared Camera/Multi-ObjectSpectrometer
NOBL	New Outer Blanket Layer
NSSC-1	NASA Standard Spacecraft Computer - Model 1
NSTS	National Space Transportation System
OCE-EK	Optical Control Electronics – Enhancement Kit

ACRONYMS (Continued)

OPS	Operations
ORI	Orbital Replacement Instrument
ORU	Orbital Replacement Unit
OTA	Optical Telescope Assembly
PCS	Pointing Control Subsystem
PIP	Payload Integration Plan
RIU	Remote Interface Unit
rms	Root-Mean-Square
RSU	Rate Sensing Unit
SA	Solar Array
SI	Science Instrument
SI C&DH	Science Instrument Control and Data Handling
SM2	Second Servicing Mission
SM3A	Third Servicing Mission A
SM4	Fourth Servicing Mission
SMOV	Servicing Mission Observatory Verification
S&MS	Structures and Mechanisms Subsystem
SSE	Space Support Equipment
SSM	Support Systems Module
SSP	Space Shuttle Program
SSRF	Shield/Shell Replacement Fabric
STIS	Space Telescope Imaging Spectrograph
STS	Space Transportation System
ST ScI	Space Telescope Science Institute

ACRONYMS (Continued)

TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
UV	Ultraviolet
VEST	Vehicle Electrical Systems Test
VIK	Voltage/Temperature Improvement Kit
WFC3	Wide Field Camera 3
WFPC2	Wide Field Planetary Camera 2

TBR List

Item	Location	Description	Assignee	Due Date
1	Table 1-2	SM4 Priorities	K.Kalinowski/440	12/1/02
2	1.3	The criterion for SM4 full success is: installation of three new RSUs, two new Battery Modules, COS, WFC3, FGS-3R, ASCS, the DSC Unit, and the Bay 5, 7 and 8 NOBLs (TBR).	K.Kalinowski/440	12/1/02
3	1.3	The criterion for SM4 minimum success is: installation of three new RSUs, two new Battery Modules, COS, WFC3, and the Bay 7 and 8 NOBLs (TBR).	K.Kalinowski/440	12/1/02

1. SCOPE

This document establishes the Level II requirements for the implementation of the Hubble Space Telescope (HST) Fourth Servicing Mission (SM4). SM4 is part of the program for preservation of HST's scientific capability over a twenty-year mission life, in accordance with requirements contained in "Level I Requirements for the Operational Phase of the HST Program" (Section 2, Document 1). SM4 will be planned to meet the objectives stated in Paragraph 1.2 below, and implemented by a visit to the HST by a Space Shuttle.

SM4 begins two hours prior to launch of the Space Shuttle, at which time all management and engineering support positions are staffed. SM4 concludes when the Servicing Mission Observatory Verification (SMOV) program is complete. Thus, SM4 has two phases: shuttle-based servicing and HST re-verification.

Appendix A, HST Fourth Servicing Mission Level II Requirements Allocation Matrix, provides a summary of the requirements contained in Sections 3 and 4 of this document. Appendix A does not include requirements that are To Be Determined (TBD) or To Be Resolved (TBR). The resolution of TBD and TBR items will include an update of Appendix A. The main body of this document shall take precedence over Appendix A in the resolution of discrepancies.

1.1 CONTROL

This document shall be controlled by the Office of the Associate Director of Flight Projects for HST, Goddard Space Flight Center (GSFC) via the HST Level II Configuration Control Board (CCB).

1.2 OBJECTIVES OF THE FOURTH SERVICING MISSION

The objectives of the Fourth Servicing Mission are threefold. The first objective is to provide enhanced Orbital Replacement Instruments (ORIs) that will satisfy the HST Level I requirements. The second objective is to replace certain failed or malfunctioning Orbital Replacement Units (ORUs)and upgrade other ORUs with new technology units that enhance and ensure the long-term scientific productivity of the HST. The third objective is to increase the orbit altitude of HST as much as Space Transportation System (STS) propellant permits, so that orbit decay will not constrain science operations or shorten mission life below Level 1 requirements.

1.2.1 SM4 First Objective Elements

The first objective, to provide enhanced ORIs that will satisfy the HST Level 1 requirements (see Section 2, Document 1), is satisfied with two servicing elements:

a. A new axial instrument, the Cosmic Origins Spectrograph (COS). The COS shall be a high-throughput ultraviolet (UV) spectrograph designed and built to observe faint astronomical point sources. The COS shall provide data with spectral resolution high

enough to determine the physical conditions in a broad range of astrophysical environments. The COS will replace the Corrective Optics – Space Telescope Axial Replacement (COSTAR) instrument in the (-V2, +V3) axial bay of the HST aft shroud.

b. A new radial instrument, the Wide Field Camera 3 (WFC3). The WFC3 is designed to provide HST with a high quality imaging capability until the end of the HST mission. Replacing Wide Field Planetary Camera 2 (WFPC2) in the –V3 radial bay, the WFC3 shall provide HST with new UV (>200 nanometers wavelength) and visible-wavelength sensitive Charge Coupled Device (CCD) detectors lacking the degradation from on-orbit exposure to radiation affecting WFPC2. Further, WFC3's Infrared (IR) Channel will provide an enhanced near-infrared imaging capability for observations at wavelengths between 0.9 and 1.7 microns.

1.2.2 SM4 Second Objective Elements

The second objective is to replace certain failed or malfunctioning ORUs and upgrade other ORUs with new-technology units that enhance and ensure the long-term scientific productivity of the HST. The replacements will maintain the operational capability and redundancy required by the Level I requirements document. If parts are no longer available, or if state-of-the-art technologies make improvements cost effective and technically feasible, enhancements may be made to equipment that replaces an in-flight degraded unit. The following identify the servicing elements manifested to meet this second objective.

a. Fine Guidance Sensor (FGS) – 3R: This unit will replace FGS-3 which has degraded performance that places its availability to the end of the HST mission in question. FGS-3R will complete the refurbishment of the FGSs.

b. Aft Shroud Cooling System (ASCS): The ASCS shall remove some of the heat generated by targeted Science Instruments (SIs) and reject it to space through an external radiator. The targeted SIs are the Advanced Camera for Surveys (ACS), the Space Telescope Imaging Spectrograph (STIS) and the COS.

c. Rate Sensing Unit (RSU) – 1R, RSU-2R, and RSU-3R: RSU-1R, RSU-2R and RSU-3R will replace the in-orbit units that contain aging gyros. The new RSUs benefit from build and process enhancements that help ensure the availability of a gyro triad to the end of the mission.

d. Battery Modules: Two battery modules, each containing three new batteries, will replace the in-orbit battery modules to ensure that HST has adequate power and electrical performance for the duration of the mission.

e. Data Management Unit (DMU) to Science Instrument Control and Data Handling (SI C&DH) Cross-Strap (DSC) Unit: The DSC Unit will increase the cross-strapping options for DMU components and provide increased redundancy to HST data management functions.

f. Multi-Layer Insulation (MLI) Repair: Damage to HST MLI was noted during Servicing Mission 2 (SM2). During SM4, replacement materials include New Outer Blanket Layers (NOBLs) and Shield/Shell Replacement Fabrics (SSRFs) will be used to restore MLI areas on HST, as time is available and contingencies dictate. Priority will be given to the Bay 5, 7 and 8 NOBLs.

In addition, the planning for the mission will include an adequate number of spare units and contingency items to ensure the complete success of each SM4 segment. Required Space Support Equipment (SSE) including Crew Aids and Tools (CATS) will also be part of the total manifest.

1.2.3 SM4 Third Objective Elements

The third objective of SM4 is to increase the orbit altitude of HST as much as STS propellant permits, so that orbit decay will not constrain science operations or shorten mission life below Level I requirements. This will be achieved by a reboost of the HST by the STS while the HST is berthed in the Cargo Bay during SM4.

a. Reboost. Reboost in SM4 is highly desired. A near-zero-eccentricity post-deployment orbit is preferred.

1.2.4 Manifested Hardware Categories and Priorities

Table 1-1 presents the servicing elements in four categories: Mission Science (MS), Mission Engineering (ME), spare and contingency. MS payload items are essential to satisfy Level I

science requirements. ME payload items enhance system reliability and correct for anomalous performance. Spare units are additional equipment manifested for redundancy and will be used only if the prime equipment becomes non-compliant during the mission. Contingency items are included in the manifest to resolve hardware problems that may arise during the planning or execution phase of the SM and require an SM4 response.

After each servicing element entry in Table 1-1, the equipment to be replaced is noted in brackets, [ ], where applicable.

Definitions:

MS: Mission Science elements required to satisfy HST Level I science requirements.

ME: Mission Engineering elements to enhance system reliability and correct for anomalous performance.

SPARE: Redundant hardware intended for use if primary replacement units become non-compliant during the mission.

Table 1-1 Servicing Mission Elements

ITEM	REPLACES	CLASSIFICATION
WFC3	[WFPC-2]	MS
COS	[COSTAR]	MS
FGS-3R	[FGS-3]	ME
ASCS		ME
RSU-1R	[RSU-1]	ME
RSU-2R	[RSU-2]	ME
RSU-3R	[RSU-3]	ME
BATTERY MODULE – 1R	[BATTERY MODULE 1]	ME
BATTERY MODULE – 2R	[BATTERY MODULE 2]	ME
DSC Unit		ME
NOBL INSTALLATION		ME
SPARE DSC Unit		SPARE
SPARE RSU		SPARE
AFT SHROUD LATCH REPAIR MECHANISMS		CONTINGENCY
FUSE MODULE ASSEMBLIES		CONTINGENCY
VOLTAGE IMPROVEMENT KIT		CONTINGENCY
ELECTRONICS CONTROL UNIT (ECU)		CONTINGENCY
SPARE OCE-EK		CONTINGENCY
SHIELD/SHELL REPLACE-MENT FABRIC (SSRFs)		CONTINGENCY

CONTINGENCY: Items required to resolve hardware problems that may arise during the planning or execution phase of the mission.

Table 1-2 establishes the relative priority of the MS and ME elements in Table 1-1. The priorities relating to contingency items will be determined as the need arises, based on the criticality of the contingency. The priority defined here is programmatic in nature. The actual sequence of events shall be governed by technical/safety requirements. The rationale for this sequence is developed through a coordination that involves GSFC Code 441/442 mission managers and Johnson Space Center (JSC) personnel.

The planning for the mission shall ensure to the maximum possible extent that no degradation to other spacecraft hardware occurs as a result of HST servicing.

1.3 MISSION SUCCESS CRITERIA

The objectives of the HST SM4 are to restore original capability, make life-extending changes, and improve HST's productivity. These activities are consistent with Hubble's design philosophy: spacecraft components are replaced as they age; science instruments and other components are improved; and expanded capabilities are installed to take advantage of state-of-the-art advances. The servicing activities are categorized as either spacecraft maintenance items or productivity enhancement items as follows:

Table 1-2 SM Priorities (TBR)

PRIORITY	ITEM
1.	RSU-1R, RSU-2R, RSU-3R
2.	Battery Module-1R, Battery Module-2R
3.	COS
4.	WFC3
5.	ASCS
6.	MLI Repair (Bay 7,8 NOBL)
7.	FGS-3R
8.	DSC Unit
9.	MLI Repair (Bay 5 NOBL)
10.	Reboost

Category 1. Spacecraft Maintenance Items

RSU-1R, RSU-2R, RSU-3R
Battery Module-1R, Battery Module-2R
FGS-3R
DSC Unit
MLI repair (Bay 5, 7, 8 NOBLs)
Orbit Reboost

Category 2. Productivity Enhancement Items

COS
WFC3
ASCS

The criterion for SM4 full success is: installation of three new RSUs, two new Battery Modules, COS, WFC3, FGS-3R, ASCS, the DSC Unit, and the Bay 5, 7 and 8 NOBLs (TBR). Other items will be completed on a time-available basis.

The criterion for SM4 minimum success is: installation of three new RSUs, two new Battery Modules, COS, WFC3, and the Bay 7 and 8 NOBLs (TBR).

2. APPLICABLE DOCUMENTS

The following documents are applicable to SM4 Level II Requirements. The latest issue is applicable unless otherwise noted.

1. Hubble Space Telescope Level I Requirements for the Operational Phase of the Hubble Space Telescope Program: Office of Space Science, Astrophysics Division, NASA Headquarters, February 29, 1996, STR-78.

2. WFC3 Contract End Item (CEI) Specification, STE-66

3. COS CEI Specification, STE-63

4. Level II Interface Control Document, SSM to Optical Telescope Assembly (OTA) Space Telescope (ST) – Interface Control Document (ICD) – ST-ICD-01F.

5. Space Shuttle System Payload Accommodations, National Space Transportation System (NSTS) 07700, Volume XIV.

6. Shuttle Orbiter/HST-SM Cargo Element Interfaces, ICD-A-14009-SM.

7. Payload Integration Plan (PIP), Space Transportation System and Space Telescope, NSTS 14009.

8. Safety Policy and Requirements for Payloads using the Space Transportation System (STS), NSTS 1700.7B

9. HST Servicing Mission Contamination Control Requirements, STR-29, Rev. A.

10. Space Telescope Mission Operations Functional Requirements, SMO-1000, Appendix L and M.

11. HST Constraints and Restrictions Document, SMO-1020L.

12. Level II Interface Control Document, Axial SI to OTA and SSM, ST-ICD-02E.

13. Level II Interface Control Document, Radial SI to OTA and SSM, ST-ICD-03F.

14. Space Shuttle Payload Ground Safety Handbook, Kennedy Space Center (KSC) Handbook (KHB), 1700.7 Rev. B.

15. Design Specification for the Tether Loop Equipped Orbital Replacement Unit Fuse Module Assembly (FMA), HDOS SD-679-1807.

16. ORU Fuse Module Assembly Tether Loop, HDOS ST-SE-5375.

17. Support System Module (SSM) Prime Equipment CEI Specification, Part 1, STE-01C.

18. Rate Gyro Assembly Specification, LMSC #4171761C.

19. Level II Interface Requirements Document, SSM to OTA, STR-01 Rev. D.

20. Optical Telescope Assembly (OTA) Prime Equipment Contract End Item Detail Specification, Part 1, STE-02 Rev. E.

21. HST NOBL/SSRF CEI Specification, STE-59.

22. HST ASCS/NCS CEI Specification, STE-55.

23. HST Voltage/Temperature Improvement Kit CEI Specification, STE-57.

24. Requirements Specification for HST Aft Shroud Latch Repair Mechanism, LMMS #P505023.

25. Detailed Specification for Nickel Hydrogen Battery Module, LMSC #4177751B.

26. Data Management Unit (DMU) to Science Instruments Control and Data Handling (C&DH) Cross-Strap (DSC) Unit, STE-71.

27. HST Code 440 Risk Management Plan, P-440-063.

28. General Environmental Verification Specification (GEVS).

29. SMR-4090 HST Fourth Servicing Mission Performance Assurance Implementation Plan.

30. SPAR-3 Standard Payload Assurance Requirements.

31. ST-ICD-04 SSM to SI C&DH Interface Control Document.

32. ST-ICD-08 SI to SI C&DH Interface Control Document.

3. REQUIREMENTS

The elements to be installed on the HST shall meet or exceed the performance requirements of the items to be replaced. These replacements shall maintain the operational capability and redundancy required by Level I. When possible, replacement items shall include upgrades necessary to provide protection against failure modes realized on orbit. While possible, manifest additions shall be considered in response to evolving assessments of risks to HST survival until 2010. (See Section 2, Document 27.)

The HST hardware manifest for SM4 shall include spare and contingency hardware deemed essential for recovery from the more probable anomalies which might arise just prior to SM4 or occur due to hardware change-out and servicing. The spare/contingency hardware shall be built and tested to standards that ensure that each unit satisfies its respective CEI specification. The minimum complement of these items shall be as specified in Table 1-1.

3.1 SERVICED SPACECRAFT HARDWARE PERFORMANCE REQUIREMENTS

The hardware manifested for SM4 falls into three categories: Heritage Items, New Items, and Modified Heritage Items. Table 3-1 shows the classification of the elements into these categories. Heritage Items are defined as units of design identical to those presently in orbit on HST. New items and Modified Heritage Items are units of a completely new design or units that have undergone refurbishment or redesign.

Table 3-1 Hardware Classification of Servicing Elements

HERITAGE ITEMS	NEW OR MODIFIED HERITAGE ITEMS
RSU-1R, 2R, 3R and spare RSU*	WFC3 (New)
Fuse Module Assemblies (Contingency)	COS (New)
Voltage Improvement Kit (Contingency)	Battery Module-1R, 2R (Modified Heritage)
Aft Shroud Latch Repair Mechanism (Contingency)	FGS-3R (Modified Heritage)
Electronics Control Unit (Contingency)	ASCS (New)
MLI Repair Materials	DSC Unit (New)
OCE-EK (Contingency)	

*some RSUs contain improved, silver-plated flex leads.

Prior to SM4, the required performance in the HST orbital environment of each manifested item shall be demonstrated, as necessary, by analysis, test, or similarity.

3.1.1 Heritage Item Requirements

Items classified as Heritage in Table 3-1 shall meet the requirements of their respective CEI specifications. Any essential new requirements imposed by SM4 launch, servicing, or post-mission on-orbit environments shall also be met. These items shall be shown to meet original and essential new requirements at the time of acceptance for SM4.

3.1.1.1 RSU-1R, RSU-2R and RSU-3R Requirements. RSU-1R, RSU-2R and RSU-3R shall be installed in the HST to replace the in-orbit units. The current in-orbit gyros have a predicted remaining life shorter than the remaining duration of the HST mission.

3.1.1.2 Voltage Improvement Kit Requirements. A contingency Voltage/Temperature Improvement Kit (VIK) shall be flown on SM4. The VIK shall replace any unit now installed between an HST battery and its corresponding Charge Current Controller (CCC) in contingencies that render the present VIK non-functional. The VIK shall adjust the family of CCC Voltage/Temperature curves available for charge management of the batteries and permit a lower-than-otherwise-selectable battery voltage to trigger charge current cutoff.

3.1.1.3 Fuse Module Assembly Requirements. A set of replacement Fuse Module Assemblies shall be flown on SM4. The assemblies shall be used to replace existing fuse modules in contin-

gencies that render the HST's present fuse module assemblies partially or wholly non-functional.

3.1.1.4 Aft Shroud Latch Repair Mechanism Requirements. A set of Aft Shroud Latch Repair Mechanisms shall be flown on SM4. The mechanism shall be used to tightly close and secure bay doors in contingencies that render the HST's present latches unable to support the same function by themselves.

3.1.1.5 Electronics Control Unit Requirements. An ECU shall be flown on SM4 as a contingency item enabling recovery from a late failure of one of the three units now in HST.

3.1.1.6 Optical Control Electronics - Enhancement Kit (OCE-EK). An OCE-EK shall be flown on SM4 as a contingency item to replace the existing OCE-EK in contingencies that render the HST's present OCE-EK partially or wholly non-functional.

3.1.2 New or Modified Heritage Item Requirements

The design and construction of items classified as New or Modified Heritage in Table 3-1 shall meet the requirements specified in the following sections. Detailed requirements for these items shall be derived and specified in respective CEI specifications or revisions. Derivation of these requirements shall conform to all applicable documents listed in Section 2.

3.1.2.1 Cosmic Origins Spectrograph Requirements. The COS shall replace the COSTAR in the (-V2, +V3) axial bay of the HST aft shroud.

The performance specifications for the COS shall be met assuming the following image stability while under FGS control and guiding in fine lock:

a. Line of sight (LOS) instrument image motion delivered by the OTA due to all causes shall be less than 0.007 arc-second, root mean square (rms), over a period of 24 hours.

b. A time average of 60 seconds of focal plane line-of-sight rms jitter shall be: less than or equal to 0.007 arc-second for no less than 95 percent of any given orbit and less than or equal to 0.012 arc-second for no less than 100 percent of any given orbit.

c. A loss of fine lock shall occur, on average, no more often than 1 out of 15 orbits.

3.1.2.2 Wide Field Camera 3 Requirements. The WFC3 shall replace the WFPC2 in the –V3 radial bay of the HST aft shroud.

The performance specifications for the WFC3 shall be met assuming the following image stability while under FGS control and guiding in fine lock:

a. LOS instrument image motion delivered by the OTA due to all causes shall be less than 0.007 arc-second, rms, over a period of 24 hours.

b. A time average of 60 seconds of focal plane line-of-sight rms jitter shall be: less than or equal to 0.007

arc-second for no less than 95 percent of any given orbit and less than or equal to 0.012 arc-second for no less than 100 percent of any given orbit.

c. A loss of fine lock shall occur, on average, no more often than 1 out of 15 orbits.

3.1.2.3 FGS-3R Requirements. FGS-3R is a flight component of HST that was replaced and returned during the Third Servicing Mission 3A (SM3A) because of degraded performance. Prior to acceptance for SM4, the unit shall be refurbished to restore its opto-mechanical performance. This restoration shall include full field-of-view performance. The refurbishment of the FGS and its compatibility with the HST Pointing Control Subsystem (PCS) shall not prevent the HST from meeting the image motion requirements stated in paragraph "a" of Section 3.1.2.1. The electrical connections needed to power and command FGS-3R's motor-actuated fold flat mirror #3 shall be made via the Optical Control Electronics – Enhancement Kit (OCE-EK) in Bay C of the OTA Equipment Section.

3.1.2.4 ASCS Requirements. The ASCS shall remove some of the heat generated by targeted SIs and reject it to space through an external radiator. The targeted SIs shall be the ACS, the STIS, and the COS. The heat rejection capability of the ASCS shall be sized to maintain targeted SI subsystems at temperatures supporting achievement of each targeted SI's science performance and reliability specifications.

3.1.2.5 DSC Unit Requirements. The DSC Unit shall be installed in HST in order to increase the tolerance of the DMU to subsystem failures and provide essential redundancy to the HST data management functions. Prior to DSC installation the functionality of the B-sides of the HST's DMU, Data Interface Unit 5, and CU/SDF shall be assessed.

3.1.2.6 Battery Module Requirements. Two battery modules, each module containing three batteries, shall be installed in the HST to replace the in-orbit battery modules. The charge capacity and electrical performance of these modules shall be adequate to support the HST for the remaining duration of the mission. The new battery modules shall contain battery isolation switches.

3.1.2.7 MLI Repair Requirements. MLI repair shall be accomplished using NOBLs (and SSRFs to address contingencies) that will withstand adverse orbital environments well enough to enable HST mission operations through 2010. In addition to existing damage, potential additional degradation that may thermally constrain or pose a debris contamination threat to the HST shall be taken into consideration in determining the amount and piece-part characteristics of the replacement material transported to orbit. The amount of material shall be complemented by flexibility of design in order to allow repair of any critical area of the spacecraft MLI likely to show severe degradation or tear which would produce a significant degradation in a scientific capability of HST.

3.1 SERVICING SUPPORT REQUIREMENTS

3.2.1 HST Orbit and Reboost

The servicing support requirements for SM4 shall be based on minimum and maximum capture altitudes for the HST of 307 and 309 nautical miles respectively.

Reboost in SM4 to increase the orbital altitude of the HST as much as STS propellant permits is highly desired. A near-zero-eccentricity orbit is preferred.

There is no requirement for re-rendezvous after deployment. There is no requirement to return the HST to the ground during SM4.

3.2.2 Return of Replaced Hardware

Mission planning shall support the return from orbit of replaced hardware. It is not a requirement for the replaced hardware to be maintained in an operational state once the successful installation of replacement hardware into the HST has been verified via a functional test of that hardware. Prior to the required verification of new hardware, functional hardware that has been removed from the HST shall be protected against conditions that would preclude its reinstallation or create a contamination risk to hardware remaining in orbit.

3.2.3 Uninstalled Replacement Hardware

Mission planning shall support the return of uninstalled replacement hardware from orbit. Planning shall provide conditions that protect such hardware from thermal environments that violate the non-operate temperature limits of the hardware. Structural loads

experienced by uninstalled hardware during nominal landings shall not preclude its re-flight.

3.2.4 HST/FSS Configuration

Any SSE needed to augment the structural integrity of the HST Flight Support System (FSS) shall be provided. The Solar Arrays (SAs) shall remain fully deployed. Planning shall define and impose, if any, limitations needed to assure the compatibility of HST servicing with deployed SAs.

3.2.5 Shuttle Support

The entire complement of payload, carriers, tools, and Extra Vehicular Activity (EVA) amenities, shall meet the requirements of NSTS 07700, Volume XIV (Section 2, Document 5). The HST payload shall meet the requirements of ICD-A-14009-SM (Section 2, Document 6), and the execution of the SM shall meet the requirements of NSTS 14009 (Section 2, Document 7). Safety requirements specified in NSTS 1700.7 and KHB 1700.7 (Section 2, Documents 8 and 14) shall be met.

3.2.6 Servicing Mission Duration

Unless precluded by equipment failures, the HST science operation shall continue through the launch of the Orbiter, which commences the shuttle phase of SM4. Provisions shall be made to extend the science operation, day for day and without interruption, in response to launch delays.

The planned duration (nominal plus reserved contingency) of shuttle-based servicing shall be sufficiently long to accomplish the replacements listed in Table 1-2 and to ensure that the HST is left in an operational state.

3.2.7 Space Support Equipment

SSE including CATS, either existing or developed, shall meet the following requirements:

a. The ORU carriers shall be designed to protect the flight replacement hardware, spares and contingency items; to transport them into orbit; and to return SM hardware, (replaced or uninstalled) from orbit.

b. The FSS shall provide support to berth, energize, reboost, and maintain the HST in a condition that permits the resumption of its science mission.

c. The SSE shall support replacement of the designated equipment by EVA.

d. The SSE design shall retain power, weight and space margins enabling the addition of schedule-feasible ORU payload items in response to critical in-orbit failures that occur late in the pre-mission cycle.

3.2.8 Contamination

The spacecraft flight hardware and SSE shall meet the contamination requirements specified in STR-29 (Section 2, Document 9).

SM hardware shall not adversely affect the cleanliness levels of the OTA, the aft shroud or the instruments remaining on-board the HST.

3.2.8.1 WFC3 Contamination. The WFC3 science instrument life cycle, from build through the integration and test activity at GSFC, pre-launch processing at KSC, delivery to orbit and installation into the HST shall ensure cleanliness levels that meet or exceed the levels specified in STR-29 (Section 2, Document 9).

3.2.8.2 COS Contamination. The COS science instrument life cycle, from build through the integration and test activity at GSFC, pre-launch processing at KSC, delivery to orbit and installation into the HST shall ensure cleanliness levels that meet or exceed the levels specified in STR-29 (Section 2, Document 9).

3.2.8.3 Orbiter and EVA Related Requirements. The HST program's requirements for the cleanliness levels of the Orbiter environment and of EVA accessories, spacesuits and other items provided by the Space Shuttle Program shall be documented in ICD-A-14009-SM and NSTS 14009 (Section 2, Documents 6 and 7). Contamination-related limitations on Orbiter activities shall also be documented therein.

3.3 FLIGHT SOFTWARE, GROUND SYSTEM, AND OPERATION PERFORMANCE REQUIREMENTS

To accommodate the new flight equipment and support the SM, changes shall be made as necessary to the ground system, operational procedures, and the HST486 Computer and National Aeronautics and Space Administration (NASA) Standard Spacecraft Com-

puter, Model-1 (NSSC-1) flight software. The ground system shall meet the requirements stated in SMO-1000, Appendix L and M and SMO-1020 (Section 2, Documents 10 and 11). The following are requirements for the ground system:

a. SM4 shall be conducted with SM4 System Readiness #4, including Control Center System (CCS) Release 4.04, HST486 Computer Software Flight Version 2.1B, and NSSC-I Release 8.1, or their respective successors.

b. The capability shall be provided to plan, develop, verify, and execute shuttle-based servicing, SMOV operations and normal operations for the new spacecraft flight hardware.

c. The ground system shall perform normal science operations while preparing for SM4.

d. The capability shall be provided for coordinated SM simulations with GSFC, JSC and KSC facilities, systems, and personnel.

e. The capability shall be provided for coordinated SM operations with Space Telescope Science Institute (ST ScI), GSFC, JSC, and KSC facilities, systems, and personnel.

f. The execution of SM4 shall be planned to minimize the amount of time during which the science program is interrupted.

g. Multiple replacements during one EVA shall be supported. The ground system shall be capable of interface verification of the replacement hardware during the same EVA.

h. The ground system shall be capable of functional checkout of the replacement hardware during the EVA in which it is installed or prior to the next EVA.

i. The ground system shall develop and support the execution of contingency procedures to isolate, troubleshoot, and resolve HST and SSE anomalies that may arise during SM4.

The NSSC-1 and HST486 Computer flight software shall meet the requirements stated in SMO-1000, Appendix L (Section 2, Document 10). The following are SM4-unique requirements for the NSSC-1 flight software:

a. The NSSC-1 flight software system support of transitions from normal science operations to SM operations and back to normal science operations shall be SI-complement-transparent.

b. The NSSC-1 flight software shall support the WFC3 embedded flight software by providing science instrument health and safety monitoring, telemetry collection and command management.

c. The NSSC-1 flight software shall support the COS embedded flight software by providing science

instrument health and safety monitoring, telemetry collection and command management.

d. The NSSC-1 flight software shall support control of the ASCS via the Remote Interface Unit (RIU) dedicated to the Near Infrared Camera/Multi-Object Spectrometer (NICMOS) Cooling System (NCS) and ASCS interface by providing health and safety monitoring, telemetry collection and command management.

4. VERIFICATION REQUIREMENTS

A verification program shall be conducted. The flow down of requirements from Level II to Level III and from Level III to Level IV shall be demonstrated. Verification matrices shall be maintained for all Level II, III, and IV systems, including spacecraft replacement hardware and software, SSE, ground system hardware, software and procedures.

All requirements shall be verified. Verification of requirements at all levels shall consist of the following as appropriate: pre-launch verification of mission systems requirements, pre-launch verification of flight hardware at developer's facilities (per applicable end-item specifications), pre-launch systems verification of flight hardware and software (subsystem and system) at GSFC and KSC, EVA task verification (requirements, hardware designs and procedures) at GSFC and JSC, and post-shuttle-phase SMOV operations. Requirements shall be verified by analysis, inspection, test, similarity or demonstration.

Critical optical performance requirements shall be subject to independent verification.

4.1 PRE-LAUNCH VERIFICATION

Verification and testing of all flight hardware and flight software shall be conducted before launch to verify compliance with the applicable end-item specification/requirements by the hardware/software developer/manufacturer during the final test program. A system-level verification shall be conducted at GSFC with the flight hardware and software integrated with the

Vehicle Electrical Systems Test (VEST) Facility and High Fidelity Mechanical Simulator (HFMS) to verify interfaces. An end-to-end compatibility test shall be performed between the flight systems and operational ground system. The functionality and mutual compatibility of the new hardware when used together in a simulated science operation shall also be tested.

The verification program for the flight hardware, flight software, and the SSE shall include the following:

a. EVA procedures and timelines
b. Optical performance
c. Contamination compliance
d. Functional performance
e. Mechanical fit, including EVA CATS interfaces
f. Flight environments (mass properties, static and dynamic loads, structural interfaces, EVA interfaces, thermal, electrical power, etc.)
g. System level compatibility
h. Safety
i. Operational readiness

Hardware designs and procedures for EVA servicing tasks shall be verified. Fidelity shall be adequate to demonstrate compliance with the Shuttle Program and the HST Project requirements.

Ground software elements shall be acceptance tested by the developer to meet the applicable specification, and then integrated into the ground system to verify compliance with system-level performance specifications to support the HST operations. The

following are verification requirements for the ground system and operations:

a. Before their use in ground system integration testing, the integrity of every command and command sequence shall be verified by the manufacturer of the new hardware.

b. Any command or command sequence which has not been validated in ground testing shall be verified via simulation or analysis, before first use in orbit.

c. SM timeline and SMOV-unique sequences shall be verified prior to in-orbit execution. As appropriate, the test environment configuration shall permit the identification of risks to in-orbit hardware that are peculiar to the planned placement of commanding within the SM4 timeline.

d. Regression testing shall be performed to verify that existing capabilities have not been degraded by the introduction of a new capability.

4.2 ON-ORBIT VERIFICATION

On-orbit verification of the new hardware and software that is installed in the HST shall be conducted. Re-verification of other HST hardware and flight software that could be affected by servicing activities and/or by the new hardware and software shall also be conducted. These verifications shall comprise the SMOV program.

Before release of the HST from the Orbiter, a functional test shall demonstrate that the replacement hardware has survived the launch environment, and has been successfully installed into the HST. As necessary, system level tests to verify Level I and II requirements possibly affected by HST servicing shall be conducted during in-bay operations. Other system level tests to verify Level I and II requirements possibly affected by HST servicing shall be conducted on the total HST system via the SMOV program.

Planned on-orbit verification activities shall not require movement of the HST secondary mirror. If necessary, scheduled secondary mirror adjustments to compensate for OTA desorption will be permitted.

SMOV activities shall include early release observations with the new and re-enabled instruments. The resulting science data products shall be released into the public domain to demonstrate the improved HST capabilities.

APPENDIX A

HUBBLE SPACE TELESCOPE

FOURTH SERVICING MISSION

LEVEL II REQUIREMENTS ALLOCATION MATRIX

A.1 INTRODUCTION AND PURPOSE

This appendix to the "Hubble Space Telescope Fourth Servicing Mission Requirements" document (STR-125) summarizes and allocates the requirements of Paragraphs 3 and 4 of the main body of the document. It is intended for use as a reference for Level III and IV requirements allocation and documentation for the Fourth Servicing Mission.

A.2 SCOPE

The requirements contained in this document encompass all activities for SM4 from the development phase of new hardware, software, procedures and processes through the SMOV of the HST observatory. Reference is made to Level I requirements, where applicable, in order to preserve flowdown traceability. All lower level requirements documents will reference the requirements contained in this document in addition to the identification of any other program document from which they were derived.

A.3 MATRIX DESCRIPTION

The Level II Requirements Allocation Matrix (Table A-1)lists all mission, replacement and support flight hardware, ground system/operations performance and verification requirements. Each requirement is attributed to one or more systems as appropriate. System acronyms used are defined as follows:

ASCS	Aft Shroud Cooling System
COS	Cosmic Origins Spectrograph

DMS	Data Management Subsystem
EPS	Electrical Power Subsystem
FGS	Fine Guidance Sensor
FSW	Flight Software
G.SYS	Ground System
GSE	Ground Support Equipment
HST	Hubble Space Telescope
OCE-EK	Optical Control Electronics – Enhancement Kit
OPS	Operations
ORI	Orbital Replacement Instrument
ORUs	Orbital Replacement Units
PCS	Pointing Control Subsystem
S&MS	Structures & Mechanisms Subsystem
SSE	Space Support Equipment
SSP	Space Shuttle Program
VEST	Vehicle Electrical Systems Test Facility
WFC3	Wide Field Camera 3

The “Lev. II Para.” Column lists the paragraph in the main body of this document from which the requirement was extracted. The “Lev. I Para.” Column lists the reference paragraph in the NASA Headquarters “Hubble Space Telescope Level I Requirements” document dated February 29, 1996 (Section 2.0, Document 1). The “Dev” column indicates that the HST Development Project is assigned responsibility for meeting the requirement; and the “OPS” column assigns the responsibility to the Operations (OPS) Project. The requirements are numbered for ease of reference.

A.4 ASSUMPTIONS AND EXPLANATIONS

As indicated in Paragraphs 3.1.2.1 and 3.1.2.2 in the main body of this document, the ORI performance requirements assume the following image stability while under FGS control and guiding in fine lock:

a. LOS instrument image motion delivered by the OTA due to all causes shall be less than 0.007 arc-second, rms, over a period of 24 hours.
b. A time average of 60 seconds of focal plane LOS rms jitter shall be: less than or equal to 0.007 arc-second for no less than 95 percent of any given orbit and less than or equal to 0.012 arc-second for no less than 100 percent of any given orbit.
c. A loss of fine lock shall occur, on average, no more often than 1 out of 15 orbits.

Some matrix items, primarily the “verification requirements” in Section 4 of STR-125 originate at Level II and are, therefore, not referenced to the Level I documents.

A.5 LOWER LEVEL REQUIREMENTS ALLOCATION MATRICES

Level III and Level IV requirements allocation matrices shall contain requirements statements, systems and subsystems identification and Levels II, III and IV traceability information.

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX

REQ. NO.	LEV.II PARA.	LEV.I PARA.	SYSTEM	REQUIREMENT	DEV.	OPS
1.	3.	2.1	ORIs ORUs	The elements to be installed on the HST shall meet or exceed the performance requirements of the items to be replaced. These replacements shall maintain the operational capability and redundancy required by Level I. When possible, replacement items shall include upgrades necessary to provide protection against failure modes realized on orbit. While possible, manifest additions shall be considered in response to evolving until 2010. (See Section 2, Document 27.)	X	X
2.	3.	2.1	ORIs ORUs	The HST hardware manifest for SM4 shall include spare and contingency hardware deemed essential for recovery from the more probable anomalies which might arise just prior to SM4 or occur due to hardware change-out and servicing. The spare/contingency hardware shall be built and tested to standards that ensure that each unit satisfies its respective CEI specification. The minimum complement of these items shall be as specified in Table 1-1.	X	
3.	3.1	2.1	ORIs ORUs	Prior to SM4 the required performance in the HST orbital environment of each manifested item shall be demonstrated, as necessary, by analysis, test, or similarity.	X	X
4.	3.1.1	2.1	ORUs	Items classified as heritage in Table 3-1 shall meet the requirements of their respective CEI specifications. Any essential new requirements imposed by SM4 launch, servicing, or post mission on-orbit environments shall also be met. These items shall be shown to meet original and essential new requirements at the time of acceptance for SM4.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
5.	3.1.1.1	2.1	PCS	RSU-1R, RSU-2R, and RSU-3R shall be installed in the HST to replace in orbit units.	X	
6.	3.1.1.2	2.1	EPS	A contingency VIK shall be flown on SM4. The VIK shall replace any unit now installed between and HST battery and its corresponding Charge Current Controller (CCC) in Contingencies that render the present VIK non-functional. The VIK shall adjust the family of CCC Voltage/Temperature curves available for charge management of the batteries and permit a lower-than-otherwise-selectable battery voltage to trigger charge current cutoff.	X	X
7.	3.1.1.3	2.1	EPS	A set of replacement Fuse Module Assemblies shall be flown on SM4. The assemblies shall be used to replace existing fuse modules in contingencies that render the HST's present fuse module assemblies partially or wholly non-functional.	X	
8.	3.1.1.4	2.1	S&MS	A set of Aft Shroud Latch Repair Mechanisms shall be flown on SM4. The mechanism shall be used to tightly close and secure bay doors in contingencies that render the HST's present latches unable to support the same function by themselves.	X	
9.	3.1.1.5	2.1	PCS	An ECU shall be flown on SM4 as a contingency item enabling recovery from a late failure of one of the three units now in HST.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
10.	3.1.1.6	2.1	FGS	An OCE-EK shall be flown on SM4 as a contingency item to replace the existing OCE-EK in contingencies that render the HST'S present OCE-EK partially or wholly non-functional.	X	
11.	3.1.2	2.1 5.4	ORI ORUs	The design and construction of items classified as New or Modified Heritage in Table 3-1 shall meet the requirements specified in the following sections. Detailed requirements for these items shall be derived and specified in respective CEI specifications or revisions. Derivation of these requirements shall conform to all applicable documents listed in Section 2.	X	
12.	3.1.2.1	3.2.1 3.2.2 5.4	COS	The COS shall replace the COSTAR in the (-V2, +V3) axial bay of the HST aft shroud.	X	X
13.	3.1.2.1	3.1.1	COS	The performance specifications for the COS shall be met assuming the following image stability while under FGS control and guiding in fine lock: a. Line of sight (LOS) instrument image motion delivered by the Optical Telescope Assembly (OTA) due to all causes shall be less than 0.007 arc second, root mean square (rms), over a period of 24 hours. b. A time average of 60 seconds focal plane line-of-sight rms jitter shall be: less than or equal to 0.007 arc sec for no less than 95 percent of any given orbit and less than or equal to 0.012 arc sec for no less than 100 percent of any given orbit. c. A loss of fine lock shall occur,on average no more often than 1 out of 15 orbits.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
14.	3.1.2.2	3.2.1 3.2.2 5.4	WFC3	The WFC3 shall replace the WFPC2 in the –V3 radial bay of the HST aft shroud.	X	X
15.	3.1.2.2	3.1.1	WFC3	The performance specifications for the WFC3 shall be met assuming the following image stability while under FGS control and guiding in fine lock: a. Line of sight (LOS) instrument image motion delivered by the Optical Telescope Assembly (OTA) due to all causes shall be less than 0.007 arc second, root mean square (rms), over a period of 24 hours. b. A time average of 60 seconds focal plane line-of-sight rms jitter shall be: less than or equal to 0.007 arc sec for no less than 95 percent of any given orbit and less than or equal to 0.012 arc sec for no less than 100 percent of any given orbit. c. A loss of fine lock shall occur,on average no more often than 1 out of 15 orbits.	X	
16.	3.1.2.3	2.1 2.3	FGS	FGS-3R is a flight component of HST that was replaced and returned during SM3A because of degraded performance. Prior to acceptance for SM4, the unit shall be refurbished to restore its opto-mechanical performance. This restoration shall include full field of view performance.	X	
17.	3.1.2.3	2.1	FGS	The refurbishment of the FGS and its compatibility with the HST Pointing Control Subsystem (PCS) shall not prevent the HST from meeting the image motion requirements stated in paragraph ‘a’ of Section 3.1.2.1.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
18.	3.1.2.3	2.1 2.3	FGS OCE-EK SSP	The electrical connections needed to power and command FGS-3Rs motor-actuated fold flat mirror #3 shall be made via the Optical Control Electronics – Enhancement Kit (OCE-EK) in Bay C of the OTA Equipment Section.	X	
19.	3.1.2.4	2.1 3.2.1	ASCS	The ASCS shall remove some of the heat generated by targeted SIs and reject it to space through an external radiator.	X	
20.	3.1.2.4	2.1 3.2.1	ASCS	The targeted SI's shall be the ACS, the STIS, and the COS.	X	
21.	3.1.2.4	2.1 3.2.1	ASCS	The heat rejection capability of the ASCS shall be sized to maintain targeted SI subsystems at temperatures supporting achievement of each targeted SI's science performance and reliability specifications.	X	
22.	3.1.2.5	2.1	DMS	The DSC Unit shall be installed in HST in order to increase the tolerance of the DMU to subsystem failures and provide essential redundancy to the HST data management functions. Prior to DSC installation the functionality of the B-sides of the HST's DMU, Data Interface Unit 5, and CU/SDF shall be assessed.	X	
23.	3.1.2.6	2.1	EPS	Two battery modules, each module containing three batteries shall be installed in the HST to replace the in-orbit battery modules. The charge capacity and electrical performance of these modules shall be adequate to support the HST for the remaining duration of the mission. The new battery modules shall contain battery isolation switches.	X	
24.	3.1.2.7	2.1 5. 6. 7.	HST	MLI repair shall be accomplished using NOBLs (and SSRFs to address contingencies) that will withstand adverse orbital environments well enough to enable HST mission operations through 2010.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
25.	3.1.2.7	2.1 5.	HST	In addition to existing damage, potential additional degradation that may thermally constrain or pose a debris contamination threat to the HST shall be taken into consideration in determining the amount and piece-part characteristics of the replacement material transported to orbit.	X	
26.	3.1.2.7	2.1 5.	HST	The amount of material shall be complemented by flexibility of design in order to allow repair of any critical area of the spacecraft MLI likely to show severe degradation or tear which would produce a significant degradation in a scientific capability of HST.	X	
27.	3.2.1	-	SSP	The servicing support requirements for SM4 shall be based on minimum and maximum capture altitudes for the HST of 307 and 309 nautical miles respectively Reboost in SM4 to increase the orbital altitude of the HST as much as STS propellant permits is highly desired. A near-zero-eccentricity orbit is preferred.	X	
28.	3.2.2	5.	SSP SSE	Mission planning shall support the return from Orbit of replaced hardware.	X	X
29.	3.2.2	5.	SSP SSE	Prior to the required verification of new hardware, functional hardware which has been removed from the HST'shall be protected against conditions that would preclude its reinstallation or create a contamination risk to hardware remaining in orbit.	X	X
30.	3.2.3	5. 5.3	SSP SSE	Mission planning shall support the return of uninstalled replacement hardware from orbit.	X	X
31.	3.2.3	5.2 5.3	SSP SSE	Planning shall provide conditions which protect such hardware from thermal environments which violate the non-operate temperature limits of the hardware.	X	X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
32.	3.2.3	5.3	SSP SSE ORI ORUs	Structural loads experienced by uninstalled hardware during nominal landings shall not preclude its re-flight.	X	X
33.	3.2.4	5.5	SSE	Any SSE needed to augment the structural integrity of the HST Flight Support System (FSS) shall be provided.	X	
34.	3.2.4	-	HST	The SAs shall remain fully deployed.	X	X
35.	3.2.4	5.2 6.1	OPS SSP	Planning shall define and impose if any, limitations needed to assure the compatibil-ity of HST servicing with deployed SAs.	X	X
36.	3.2.5	6.1	ORIs ORUs SSE	The entire complement of payload, carriers, tools, and extravehicular activity (EVA) amenities, shall meet the requirements of NSTS 07700, Volume XIV (Section 2, Document 5).	X	
37.	3.2.5	2.4	ORIs ORUs SSE G.SYS	The HST payload shall meet the requirements of ICD-A-14009-SM (Section 2, Document 6), and the execution of the servicing mission shall meet the requirements of NSTS 14009 (Section 2, Document 7).	X	X
38.	3.2.5	6.1	ORIs ORUs SSE HST G.SYS	Safety requirements specified in NSTS 1700.7 and KHB 1700.7 (Section 2, Documents 8 and 14), shall be met.	X	X
39.	3.2.6	4.2 5.2	HST G.SYS OPS	Unless precluded by equipment failures, the HST science operation shall continue through the launch of the orbiter which commences each shuttle phase of SM4. Provisions shall be made to extend the science operation, day for day and without interruption, in response to launch delays.		X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
40.	3.2.6	5.2	SSP	The planned duration (nominal plus reserved contingency) of shuttle-based servicing shall be sufficiently long to accomplish the required replacements listed in Tables 1-2 and to ensure that the HST is left in an operational state.	X	X
41.	3.2.7	5.5	SSE	The ORU Carriers shall be designed to protect the flight replacement hardware, spares, and contingency items; to transport them into orbit; and to return SM hardware (replaced or uninstalled) from orbit.	X	
42.	3.2.7	5.5	SSE	The FSS shall provide support to berth, energize, reboost, and maintain the HST in a condition which permits the resumption of its science mission.	X	
43.	3.2.7	5.5	SSE	The SSE shall support replacement of the designated equipment by EVA.	X	
44.	3.2.7	5.5	SSE	The SSE design shall retain power, weight and space margins enabling the addition of schedule-feasible ORU payload items in response to critical in-orbit failures that occur late in the pre-mission cycle.	X	
45.	3.2.8	3.1	SSE ORIs ORUs	The spacecraft flight hardware and SSE shall meet the contamination requirements specified in STR-29 (Section 2, Document 9).	X	
46.	3.2.8	3.1	SSE ORIs ORUs	SM hardware shall not adversely affect the cleanliness levels of the OTA, the aft shroud or the instruments remaining on-board the HST.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
47.	3.2.8.1	3.1	WFC3	The WFC3 science instrument life cycle, from build through the integration and test activity at GSFC, pre-launch processing at KSC, delivery to orbit and installation into the HST shall ensure cleanliness levels that meet or exceed the levels specified in STR-29 (Section 2, Document 9).	X	
48.	3.2.8.2	3.1	COS	The COS science instrument life cycle, from build through the integration and test activity at GSFC, pre-launch processing at KSC, delivery to orbit and installation into the HST shall ensure cleanliness levels that meet or exceed the levels specified in STR-29 (Section 2, Document 9).	X	
49.	3.2.8.3	2.4 3.1	SSP	The HST program's requirements for the cleanliness levels of the orbiter environment and of EVA accessories, spacesuits and other items provided by the space shuttle program shall be documented in ICD-A-14009-SM and NSTS 14009 (Section 2, Documents 6 and 7). Contamination-related limitations on orbiter activities shall also be documented therein.	X	
50.	3.3	4.	G.SYS FSW	To accommodate the new flight equipment and support the servicing mission, changes shall be made as necessary to the ground system, operational procedures, and the HST486 Computer and National and Aeronautics and Space Administration (NASA) Standard Spacecraft Computer Model-1 (NSSC-1) flight software.		X
51.	3.3	4.	G.SYS	The ground system shall meet the requirements stated in SMO-1000, Appendix L and M and in SMO-1020 (Section 2, Documents 10 and 11).		X
52.	3.3		G.SYS FSW	SM4 shall be conducted with SM4 System Readiness 4, including Control Center System (CCC) Release 4.04, HST486 Computer Software Flight Version 2.1B, and NSSC-I Release 8.1, or their respective successors.		X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
53.	3.3	4.1	G.SYS FSW SSE ORIs ORUs OPS SSP	The capability shall be provided to plan, develop, verify, and execute shuttle-based servicing, SMOV operations and normal operations for the new spacecraft flight hardware.	X	X
54.	3.3	4.2	G.SYS OPS	The ground system shall perform normal science operations while preparing for the SM4.		X
55.	3.3	4.2.3	G.SYS OPS SSP	The capability shall be provided for coordinated SM simulations with GSFC, JSC, and KSC facilities, systems, and personnel.	X	X
56.	3.3	4.2.3	G.SYS OPS	The capability shall be provided for coordinated SM operations with Space Telescope Science Institute (ST ScI), GSFC, JSC, and KSC facilities, systems, and personnel.	X	X
57.	3.3	4.2.2	OPS	The execution of the SM4 shall be planned to minimize the amount of time during which the science program is interrupted.	X	X
58.	3.3	4.2.3 5.2	G.SYS ORIs ORUs SSE OPS SSP	Multiple replacements during one EVA shall be supported.	X	X
59.	3.3	4.2.3	G.SYS OPS ORIs ORUs SSE	The ground system shall be capable of interface verification of the replacement hardware during the same EVA.	X	X
60.	3.3	4.2.3	G.SYS OPS ORIs ORUs SSE	The ground system shall be capable of functional check-out of the replacement hardware during the EVA in which it is installed or prior to the next EVA.	X	X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
61.	3.3	4.2.3	G.SYS OPS ORIs ORUs SSE	The ground system shall develop and support the execution of contingency procedures to isolate, trouble-shoot, and resolve HST and SSE anomalies that may arise during SM4.	X	X
62.	3.3	3.	FSW OPS	The NSSC-I and HST486 Computer flight software shall meet the requirements stated in SMO-1000, Appendix L and J (Section 2 and 10).		X
63.	3.3	-	FSW OPS	The NSSC-I flight software system support of transitions from normal science operations to SM operations and back to normal science operations shall be SI-complement-transparent.		X
64.	3.3	3.	FSW OPS	The NSSC-I flight software shall support the WFC3 embedded flight software by providing science instrument health and safety monitoring, telemetry collection and command management.		X
65.	3.3	3.	FSW OPS	The NSSC-I flight software shall support the COS embedded flight software providing science instrument providing health and safety monitoring, telemetry, collection and command management.		X
66.	3.3	3.4	FSW OPS G.SYS	The NSSC-I flight software shall support control of the ASCS via the RIU dedicated to the NICMOS Cooling System (NCS) and ASCS interface by providing health and safety monitoring, telemetry collection and command management.		X
67.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	A verification program shall be conducted.	X	X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
68.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	The flow down of requirements from Level II to Level III and from Level III to Level IV shall be demonstrated.	X	X
69.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	Verification matrices shall be maintained for all Level II, III, and IV systems, including spacecraft replacement hardware and software, SSE, ground system hardware, software, and procedures.	X	X
70.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	All requirements shall be verified.	X	X
71.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	Verification of requirements at all levels shall consist of the following, as appropriate: pre-launch verification of mission systems requirements, pre-launch verification of flight hardware at developer's facilities (per applicable end-item specifications), pre-launch systems verification of flight hardware and software (subsystem and system) at GSFC and KSC, EVA task verification (requirements, hardware designs and procedures) at GSFC and JSC, and post-shuttle-phase SMOV operations.	X	X
72.	4.	-	G.SYS FSW ORIs ORUs SSE OPS	Requirements shall be verified by analysis, inspection, test, similarity or demonstration.	X	X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
73.	4.	-	FGS ORIs	Critical optical performance requirements shall be subject to independent verification.	X	
74.	4.1	-	FSW ORIs ORUs SSE	Verification and testing of all flight hardware and flight software shall be conducted before launch to verify compliance with the applicable end-item specification/requirements by the hardware/software developer/manufacturer during the final test program.	X	X
75.	4.1	-	G.SYS FSW ORIs ORUs GSE VEST	A system-level verification shall be conducted at GSFC with the flight hardware and software integrated with the Vehicle Electrical System Test (VEST) Facility and High Fidelity Mechanical Simulator (HFMS) to verify interfaces.	X	X
76.	4.1	-	G.SYS FSW ORIs ORUs SSE	An end-to-end compatibility test shall be performed between the flight systems and operational ground system.	X	X
77.	4.1	-	G.SYS FSW ORIs ORUs VEST	The functionality and mutual compatibility of the new hardware when used together in a simulated science operation shall also be tested.	X	X
78.	4.1	-	HST ORIs ORUs SSP SSE	EVA procedures and timelines shall be verified.	X	
79.	4.1	-	FGS ORIs	Optical performance shall be verified.	X	
80.	4.1	-	GSE ORIs ORUs SSE	Contamination compliance shall be verified.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
81.	4.1	-	ORIs ORUs SSE G SYS FSW OPS	Functional performance shall be verified.	X	X
82.	4.1	-	ORIs ORUs SSE	Mechanical fit, including EVA CATS interfaces shall be verifies.	X	
83.	4.1	-	ORIs ORUs SSE	Flight environments (mass properties, static and dynamic loads, structural interfaces, EVA interfaces, thermal electrical power, etc.) shall be verified.	X	
84.	4.1	-	ORIs ORUs FSW HST GSE G SYS	System level compatability shall be verified.	X	X
85.	4.1	-	ORIs ORUs SSE FSW	Safety shall be verified.	X	X
86.	4.1	-	G SYS FSW OPS SSE SSP	Operational readiness shall be verified.	X	X
87.	4.1	-	SSP ORIs ORUs SSE	Hardware designs and procedures for EVA servicing tasks shall be verified.	X	

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
88.	4.1	-	SSP ORIs ORUs SSE VEST	Fidelity shall be adequate to demonstrate compliance with the Shuttle Program and the HST Project requirements.	X	X
89.	4.1	-	OPS G.SYS	Ground software elements shall be acceptance tested by the developer to meet the applicable specification, and then integrated into the ground system to verify compliance with system-level performance specifications to support the HST operations.		X
90.	4.1	-	G.SYS FSW OPS ORIs ORUs SSE	Before their use in ground system integration testing the integrity of every command and command sequence shall be verified by the manufacturer of the new hardware.	X	X
91.	4.1	-	G.SYS FSW OPS VEST	Any command or command sequence which has not been validated in ground testing shall be verified via simulation or analysis, before first use in orbit.	X	X
92.	4.1	-	G.SYS OPS VEST	Servicing mission timeline and SMOV-unique sequences shall be verified prior to in-orbit execution.	X	X
93.	4.1	-	VEST	As appropriate, the test environment configuration shall permit the identification of risks to in-orbit hardware that are peculiar to the planned placement of commanding within the service timeline.	X	X
94.	4.1	-	HST OPS	Regression testing shall be performed to verify that existing capabilities have not been degraded by the introduction of a new capability.	X	X

TABLE A-1. LEVEL II REQUIREMENTS ALLOCATION MATRIX (Continued)

Req. No.	Lev. II Para.	Lev. I Para.	System	Requirements	DEV.	OPS
95.	4.2	-	OPS ORIs ORUs	On-orbit verification of the new hardware and software that is installed in the HST shall be conducted.		X
96.	4.2	-	HST OPS	Re-verification of other HST hardware and flight software that could be affected by servicing activities and/or by the new hardware and software shall also be conducted.		X
97.	4.2	-	HST ORIs ORUs OPS	Before release of the HST from the Orbiter, a functional test shall demonstrate that the replacement hardware has survived the launch environment, and has been successfully installed into the HST.		X
98.	4.2	-	HST OPS	As necessary, system level tests to verify Level I and II requirements possibly affected by HST servicing shall be conducted during in-bay operations.		X
99.	4.2	-	HST OPS	Other system-level tests to verify Level I and II requirements possibly affected by HST servicing shall be conducted on the total HST system via the SMOV program.		X
100.	4.2	-	OPS	Planned on-orbit verification activities shall not require movement of the HST secondary mirror.		X
101.	4.2	-	OPS	SMOV activities shall include early release observations with the new and re-enabled science instruments.		X
102.	4.2	-	OPS	The resulting science data products shall be released into the public domain to demonstrate the improved HST capabilities.		X